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GUIDANCE FOR ENERGY CONTROL SYSTEM ANALYSIS.(U)
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GUIDANCE FOR ENERGY CONTROL SYSTEM ANALYSIS

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Fort Belvoir, VA 22060

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The technique and information necessary to analyze an Army installation for the economics of an energy control system are detailed. The various building information, schemes and equipment control are outlined, with an explanatory example of calculating the savings and cost of implementing energy control. Development of the simple payback equations and calculations are outlined.

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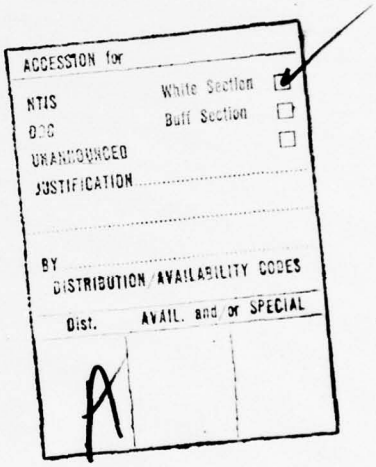

GUIDANCE FOR ENERGY CONTROL SYSTEM ANALYSIS

1.0 Gather Preliminary Data

1.1 Obtain a copy of the building information schedule (BIS). It is a compilation of various parameters for each building on post. The legend, (first 3 pages), explains the location and meaning of the various codes. Items of special interest are total square feet, system types, use, and utility service to the building. The BIS can be found at the office of Plans and Policies in the FE Shop.

1.2 Locate all electric, gas and oil bills for each facility. This information serves as the base for energy saving through conservation schemes. Obtain base wide energy bills and utility rate schedules spanning 12 months of service. This information is necessary for calculating savings from load shaving, and can be obtained from the budget department of the Post Facility Engineer. Sample electric and gas bills are displayed in Figures 1 and 2, with pertinent information underlined.

1.3 Discuss with the Facility Engineer, system type and control schemes which might apply to the post. Three levels of control are available: Level A, local, Level B, manually operated central centers, and Level C, automatic central systems. Examples of equipment used with each are respectively, time clocks, hardwired microprocessors, and programable minicomputers.

Level A controls are limited in their functions to one conservation scheme such as enthalpy or temperature controls. Level B controls can perform several functions collectively, but any change in the system operation requires hardware alteration. Level C systems are capable of optimizing all conservation schemes plus load management, and preventive maintenance programming. System modifications are performed through software changes, thus limiting expensive hardware modifications.

1.4 The various conservation schemes are described below with applicable control schemes indicated by defining letter.

1.4.1 Scheme 1, Equipment Shutdown. Programmed shutdown of building heating and cooling equipment during unoccupied periods results in significant energy savings. The magnitude of the savings depends on the heat transfer characteristics of the building, equipment capacity, type, and operating efficiency, and outside temperature conditions. (A, B, C)*

1.4.2 Scheme 2, Outside Air Shutoff. Programmed shutoff of outside air consists of closing outside air intakes and shutdown of exhaust fans when the building is unoccupied. For buildings where equipment operates continuously, the savings in energy cost can be large. It is recommended that Scheme 2 be used in conjunction with Scheme 1. (A, B, C)

1.4.3 Scheme 3, Outside Air Reduction. Many building systems have been found to draw in more outside air than is required for adequate ventilation.

*Denotes applicability of Level A, B, and C control.

)CO VIRGINIA ELECTRIC AND POWER COMPANY

FORT MONROE
PURCHASE/CONTRACT DIV
FORT MONROE VA 23351

ACCOUNT NUMBER 99 40 20 038

JUL 1975

9

ITEMIZED STATEMENT OF SERVICE

LOCATION	METER NUMBER	READ DATE	DAYS	PRES READ	CONS-TANT	USAGE	AMOUNT
	50796282	JUL 24	30	25691	2400	724800	
	50796284	JUL 24	30	27395	2400	885600	
	50699242	JUL 24	30	8293	2400	309600	
				TOTAL KWHR		1920000	27,688.87

W MTR NO.	ON	OFF	TOTAL	MINIMUM		BILLED	
02152862	4,972	2,854	4,972	2,354		4,972	15,693.81
		06012037			RKVA	2320	355.42
			TOTAL ELECTRIC SCHEDULE 60				43,738.10
		PAY THIS AMOUNT					43,738.10

Unit Energy Price = $\frac{\text{Total Cost}}{\text{Energy Consumed}} \times 10^3 = \frac{43,738.10}{1,920,000} \times 10^3$

22.78 mills/KWh;
Where 1 mill = 10^{-3} dollars

PAST DUE ON AUG 19 1975

INCLUDES FOSSIL FUEL ADJUSTMENT $0.008480 PER KWHR

Courtesy of Ft. Monroe
Sample Electric Bill
FIGURE I

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COURTESY OF FT. MONROE
SAMPLE GAS BILL
FIGURE II

290.3C VIRGINIA ELECTRIC AND POWER COMPANY

CONTR DA-BB-25-69-C-0002

U S GOVERNMENT
PURCHAS & CONTRACT DIV
FORT MONROE VA 23351

30 NN
61200

FOR GAS SERVICE - MONTH OF

METER NO.	PRESENT DATE	PRESENT READING	PREVIOUS DATE	PREVIOUS READING	DIFFERENCE	CORR. FACTOR	CCF	SCHEDULE NUMBER 5
20754	2-17-76	01656	1-20-76	69466	32190	1.5245	49,073	DEMAND /
72259	"	64648	"	20022	42626	1.5245	64,983	ACTUAL CCF
175	"	80052	"	80052	00	1.5245	00	5625
			LESS ST. MARY'S USAGE				- 4	MINIMUM CCF
			TOTAL CCF BILLED MCN. NO. 05				114,052	5925
								BILLING DEMAND CCF 5925
								AMOUNT
						COMMODITY CHARGE	9,774.26	
PURCHASED GAS ADJUSTMENT @ $ .0473						PER 100 CU. FT.	5,324.66	
						DEMAND CHARGE	3,814.00	

PSIG = AVER. MAX DAY DEL. PRESS:
(8.0 PSIG + 14.73)/14.91 = CORRECTION FACTOR

CURRENT BILL	$	18,912.92
PAST DUE ACCT.	$	.
TOTAL AMOUNT DUE	$	

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Therefore, each building system should be investigated to determine how much the outside air quantity may be reduced. An adjustment of the minimum outside air damper setting to decrease the outside quantity could be a one time adjustment or could be combined with variable setting equipment as in Scheme 2, 4 or 5. Scheme 2 and 3 should be used in conjunction.

1.4.4 Scheme 4, Enthalphy Control. A popular energy conserving scheme is that of the air side economizer. The concept utilizes outside air as a source of free cooling whenever it is cool or dry enough. The difficulty comes in activating the economizer when outside air can be used. Measuring the total heat content or enthalpy of outside air allows control of the economizer to achieve the maximum savings possible. (A, B, C)

1.4.5 Scheme 5, Enthalpy Optimization. An extension of the concepts described in enthalpy control is that of enthalpy optimization. This control scheme selects the air stream (outside air or return air) which will impose the lowest cooling load on the mechanical equipment. Selection is based on the air stream with the lowest enthalpy. It should be noted that either Scheme 4 or 5 should be used but not both. (A, B, C)

1.4.6 Scheme 6, Temperature Reset. Energy savings are available through reset or adjustment of air temperature in mixed air system like double duct and multizone. The basic concept is to decrease the amount of mixing by reducing the temperature difference between the hot and cold air streams. (A, B, C)

1.4.7 Scheme 7, Chiller Load Optimization. Efficiency decreases as the load decreases. Therefore, it is desirable to load each chiller as much as possible, especially in the case of multiple equipment. (C)

1.4.8 Scheme 8, Forecasting Peak Reduction. Peak reduction under this scheme is accomplished by shutting down selected equipment (shedding) when desirable to reduce a peak during any demand interval. (C)

1.4.9 Scheme 9, Programmed Peak Reduction. Under this scheme the demand of the system is not monitored or projected. The peak demand period is determined by investigating historical data on the system and producing demand profiles. (C)

1.4.10 Scheme 10, Maintenance Programming. This scheme would include an equipment run time program and a preventive maintenance (PM) program). (B, C)

1.4.11 Scheme 11, Fire and Intruder Detection. Self evident. (B, C)

1.4.12 Scheme 12, Equipment Logging. This scheme will chart equipment load characteristics and consumption data. (C)

1.5 Investigate the possibility of using telephone lines. If lines are not available or feasible, obtain prints of the post's maps for optimal placement of cables and equipment location.

1.6 Inquire with the Office of Plans and Policy at the FE Shop about current or future construction and demolition plans. If new facilities are on the horizon, they should be included as candidate buildings. Facilities scheduled for destruction should be passed over.

2.0 Design Plan

2.1 Using the BIS in conjunction with a building survey, tentative candidates should be selected. Four factors must be identified during the selection process; they are as follows:

- (a) Building size
- (b) Usage pattern
- (c) Heating and cooling system
- (d) Relative building location.

2.1.1 Building Size. Building size is usually the most significant factor in the selection process. The greater the total floor area, the greater the energy consumption. One notable exception is in warehouses and shop buildings. By nature these buildings encompass large floor areas which are usually not centrally heated or cooled. In general, the larger buildings with large HVAC systems are the most attractive for connection to a central system. Smaller buildings having a variety of HVAC systems throughout the structure may be more attractive for local control.

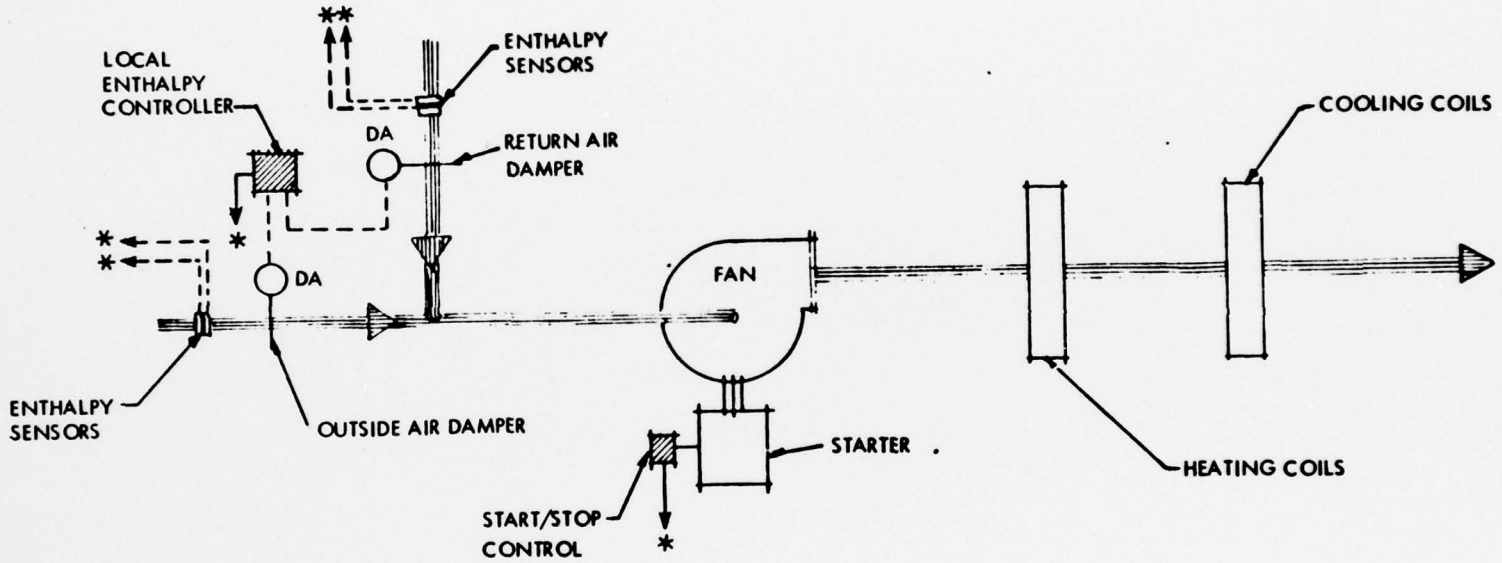
2.1.2 Usage Pattern. Patterns of building usage effect energy consumption to a large extent. Recreational centers with heavy part-time occupancy tend to have the greatest potential for conserving energy followed by office buildings. Building savings is almost proportional to the inverse of the hours of occupancy.

2.1.3 Heating and Cooling System. The type of heating and cooling system can influence the energy savings potential as well as the expense of conversion to a central control system. Generally, central heating and cooling systems found in larger, more complex buildings usually produce the greatest savings potential. System components such as air handling units, chillers, and boilers are usually located in the same area of the building, thus simplifying control system modifications.

2.1.4 Relative Building Cost. If telephone lines cannot be employed, the system's cost effectiveness becomes a function of the building's location. Some buildings may require modifications for ECS hook up. These buildings may possess high potential, but must be eliminated because of staggering communication or renovation cost. In such cases, local controls should be considered.

2.2 Investigate the HVAC systems found in the candidate buildings. Pay particular attention to system control and name plate information. If the system is scheduled for renovation or replacement, the future system should be designed with control interfacing in mind. It is advised that personnel from the Facility Engineer Shop accompany the investigators. Generic HVAC system schematic and control point descriptions are included as Figures 3 through 6, and should be consulted during the selection process.

2.3 After completing the investigation, determine applicable saving schemes for each facility. If an accepted method or reliable data for estimating savings from the various schemes exist it can be used to predict saving, otherwise the following method can be used.



DA = DAMPER ACTUATOR

* = To Central Console

FIGURE 3
SINGLE ZONE DIRECT EXPANSION SYSTEM

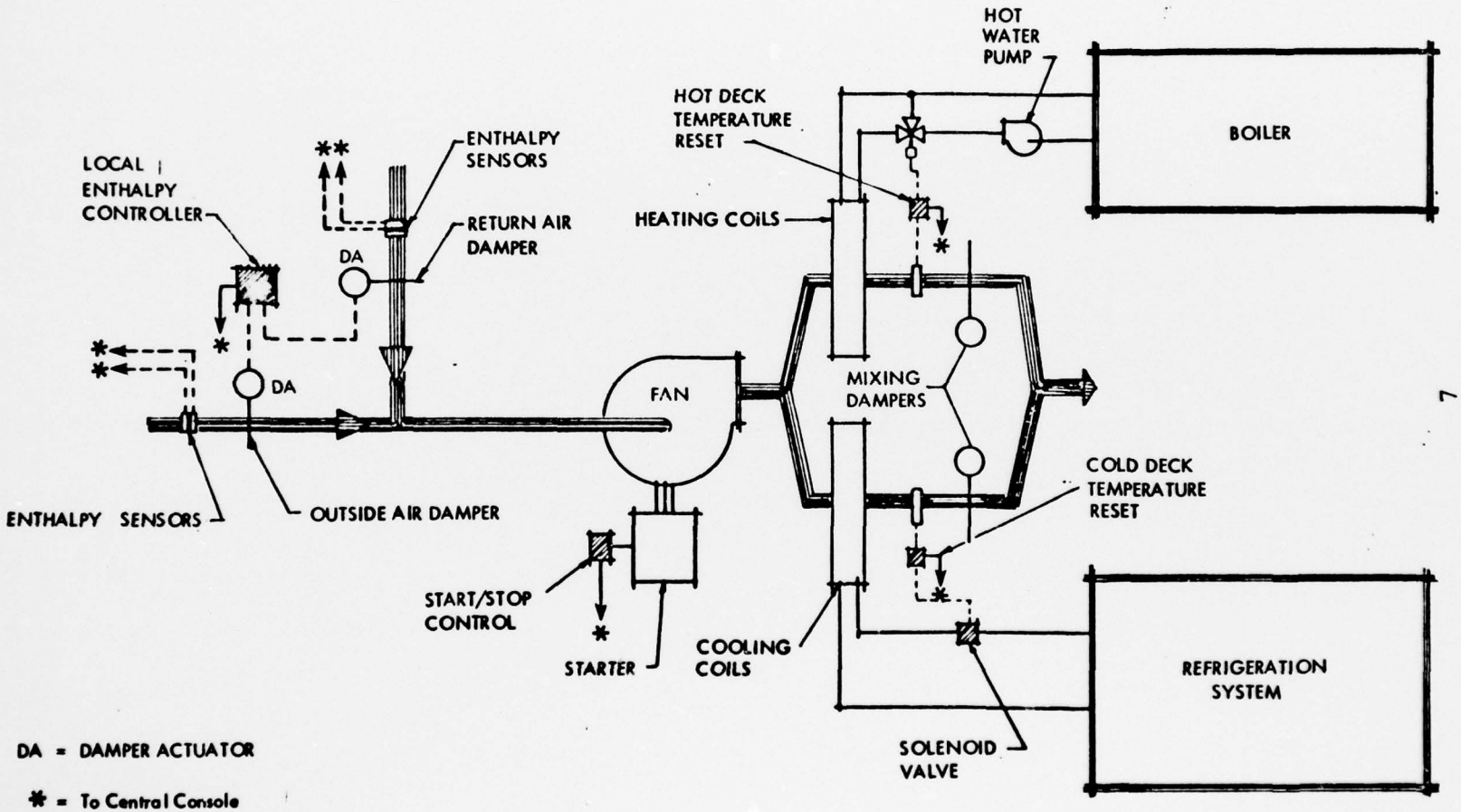


FIGURE 4
MULTIZONE CHILLED WATER SYSTEM

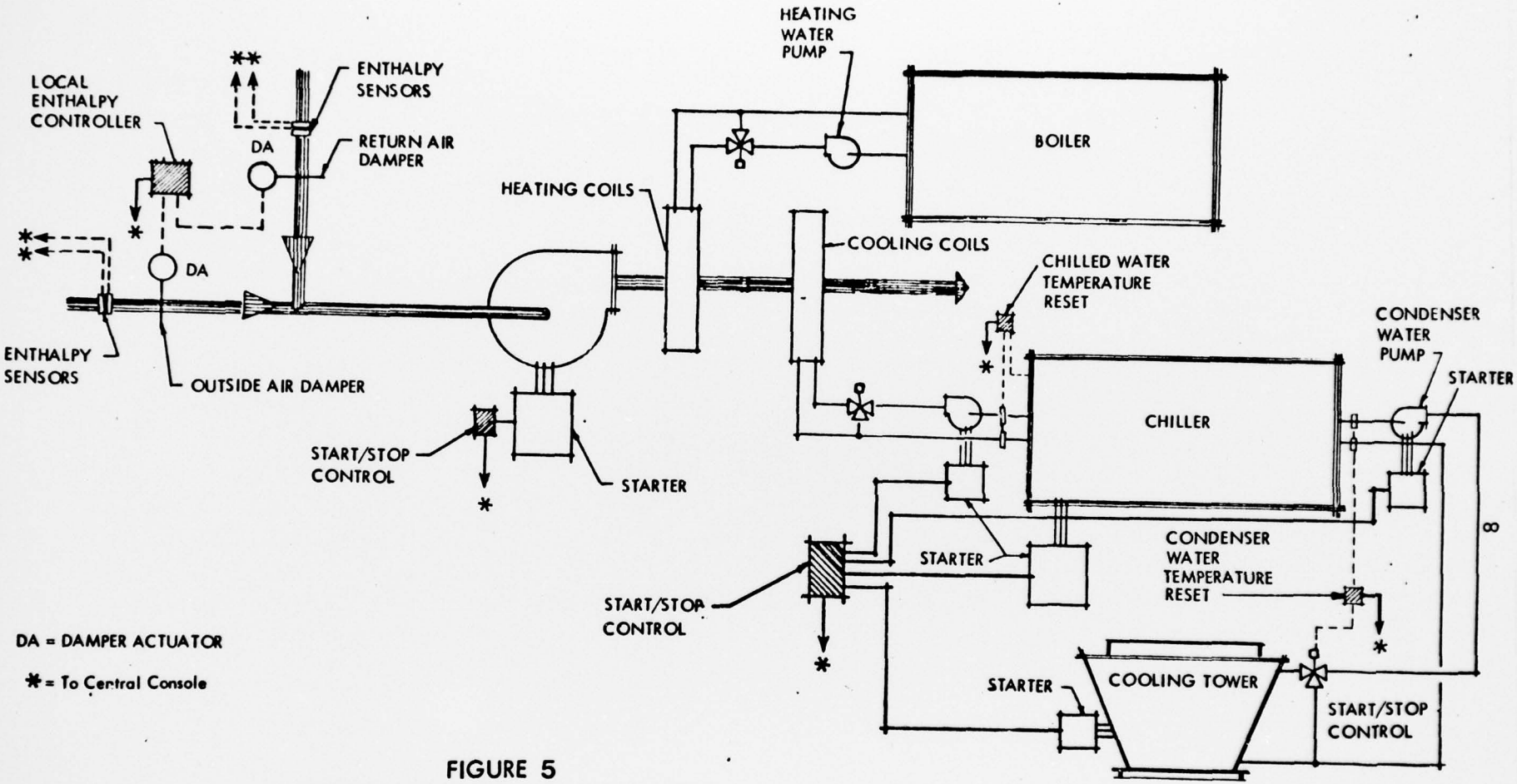


FIGURE 5
SINGLE ZONE CHILLED WATER SYSTEM

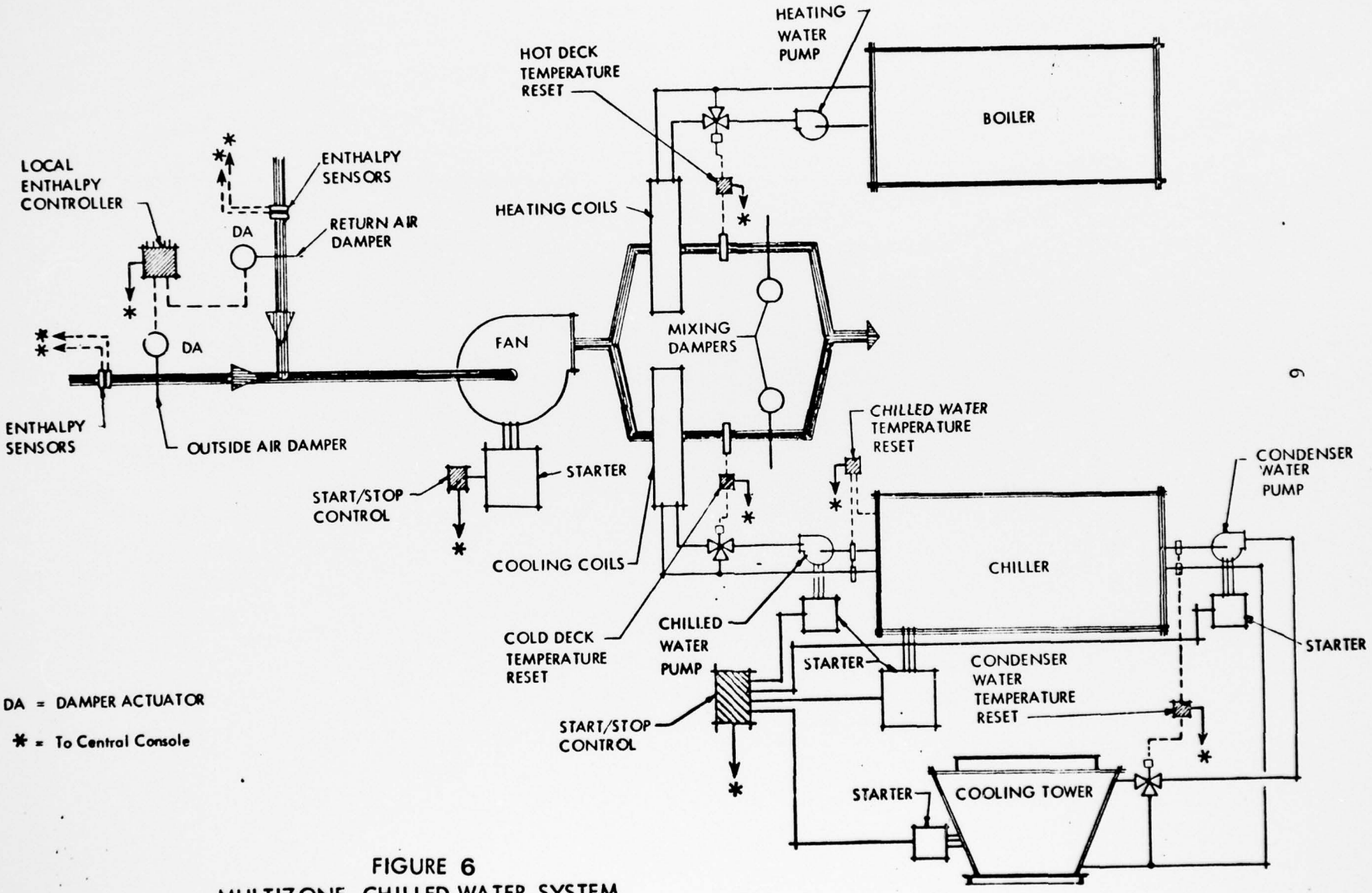


FIGURE 6
MULTIZONE CHILLED WATER SYSTEM

Schemes 1, 2, 3, and 4 or 5

The following equation can be used to estimate both cooling and heating saving for schemes 1, 2, 3 and 4 or 5, provide the proper coefficients are used. These coefficients are located in Table 1.

SF_i = Saving Factor; i = 1, 2, ...5

AR = Air Reduction, scheme 3 only

T_o = Total Energy Consumed

TS = Total Savings

Recall Schemes 4 and 5 should not be used in conjunction. Either 4 or 5 can be used but not both and these apply only to cooling. It is also assumed that Schemes 2 and 3 are always used in conjunction.

$$TS = T_o \; SF_1 + SF_2(1-SF_1) + SF_3(1-SF_2)\;(1-SF_1)\;(AR) + SF_4\;(1-SF_3)\;(1-SF_2)\;(1-SF_1)$$

$$+SF_5(1-SF_4)\;(1-SF_3)\;(1-SF_2)\;(1-SF_1)$$

Note: $SF_4 = SF_5$, when Scheme 4 is used $SF_5 = 0$, if Scheme 5 is used $SF_5 = SF_4$ and SF_4 becomes zero.

Example

Suppose an office building consumes 10^6 KBTU/Year (heating) and that Schemes 1, 2 and 3 are favorable. Further assume that the outside air will be reduced by 10%. To calculate the total savings locate savings for office buildings.

$SF_1 = .18$

$SF_2 = .30$

$SF_3 = .11$

AR = .10

$T_o = 10^6$ KBTU's/year

$TS = 10^6$ KBTU's/year .18 + .30(1-.18) + .11(1-.3)(1-.18)(.10) + 0(1-.11) 0 (1-.18) + 0(1-0) 0(1-.3)(1-.18)

$TS = 10^6$ KBTU's/year .43

$TS = 4.3 \times 10^5$ KBTU's/year.

This is the estimated energy saving for the conservation schemes employed. If T_o is unknown the following method can be used to estimate building consumption for both heating and cooling.

BEC = Baseline Energy Consumption

AADD = Average Annual Degree Days

T_o = BEF x Area x AADD/Z

Z = 4,258 for heating (heating degree days)
Z = 1,659 for cooling (cooling comfort factor)

BEC's and AADD can be found in Tables 2 and 3 respectively. The values for the SF's and BEC were developed using the ECUBE simulation.

Scheme 6

Generally potential savings from this scheme is difficult to calculate. A method for estimating the savings has been derived (Ref. 1). Care must be taken to use proper values for the flow rate and the enthalpy difference, especially if any conservation measures reduce the design temperature, enthalpy or flow rate.

Cooling Savings: $Kwh = \frac{4.5 \times CFM \times h \times hours}{3412}$

Heating Savings: BTUh = CFM x T x 1.08

where; CFM = Cubic feet per minute
h = enthalpy difference

Peak Shaving: (Total KWh Reduced) x (Demand metering period/1 hour) x (Demand Charge) = $ saved from peak shaving.

All other savings must be either measured or determined by other means. Finally, sum the seasonal energy savings for each fuel.

2.4 Using the unit energy cost calculated in 1.2 convert the above energy savings into dollars. This puts all parameters on a common base, thus allowing comparison.

2.5 Buildings with small savings should be eliminated at this point.

2.6 Choose which level of control should be used. Buildings eliminated in 2.5 may be candidates for local control (time clocks, etc) In many cases, a mix of all these (A, B, & C) may best satisfy installation needs.

TABLE I
HEATING Schemes

BUILDING TYPE	1	2	3
1. Recreation Center	.23	.37	.22
2. Theater	.21	.35	.07
3. Bowling Alley	.12	.19	.09
4. NCO Club	.11	.17	.24
5. Post Exchange	.07	.11	.02
6. Commissary	.02	.03	.09
7. Enlisted Men's Mess	.25	.41	.19
8. Laundry	.03	.05	*
9. Field House	.03	.05	*
10. Chapel	.05	.08	.01
11. Library	.11	.17	.02
12. Office Building	.18	.30	.11
13. Laboratory	.16	.27	.03
14. Laboratory	.08	.14	.07
15. Barracks	.03	.05	.01
16. BOQ	.01	.02	.003
17. Machine Shop	.09	.15	*
18. Warehouse	.03	.06	*
19. Dental Clinic	.22	.35	.03

*Energy savings must be treated for specific cases, generalized figures unavailable.

TABLE I (Cont'd)
COOLING

BUILDING TYPE	SCHEMES			
	1	2	3	4
1. Recreation Center	.09	.15	.22	.24
2. Theater	.14	.23	.07	.21
3. Bowling Alley	.02	.03	.09	.10
4. NCO Club	.03	.05	.23	.15
5. Post Exchange	.05	.08	.02	.05
6. Commissary	.02	.04	.08	.02
7. Enlisted Men's Mess	.06	.08	.19	.05
8. Laundry	*	*	*	*
9. Field House	*	*	*	*
10. Chapel	.06	.11	.01	.18
11. Library	.02	.03	.01	.22
12. Office Building	.10	.16	.11	.13
13. Laboratory	.08	.13	.03	.11
14. Laboratory	.05	.09	.07	.09
15. Barracks	.03	.05	.01	.08
16. BOQ	.01	.02	.003	.11
17. Machine Shop	.14	.23	*	*
18. Warehouse	.04	.06	*	*
19. Dental Clinic	.11	.18	.03	.13

*Energy Savings must be treated for specific cases, generalized figures unavailable.

TABLE II
BASELINE ENERGY CONSUMPTION

Military Building Type	Heating Baseline Energy Consumption In Thousands Of BTU Per Ft^2 - Year	Cooling Baseline Energy Consumption In Thousands Of BTU Per Ft^2 - Year
E.M. Recreation Center	92	58
Theatre	193	39
Bowling Alley	36	107
NCO Club	92	123
Post Exchange	171	120
Commissary	19	24
E.M. Mess	88	139
Laundry (See Note 1)	117	-
Field House (See Note 1)	40	-
Chapel	122	36
Library	11	27
Office Building (See Note 2)	78	36
Laboratory (See Note 3)	83	66
Laboratory (See Note 4)	42	19
Barracks	28	22
BOQ (See Note 5)	77	35
Machine Shop (See Note 1)	43	54
Warehouse (See Note 1)	56	41
Dental Clinic	76	43

TABLE III
AVERAGE ANNUAL DEGREE DAYS

City	Heating Degree Days	Cooling Degree Days
Abilene, Texas	2,657	2,394
Albuquerque, New Mexico	4,389	1,038
Amarillo, Texas	4,345	1,401
Atlanta, Georgia	2,811	2,152
Bakersfield, California	2,115	1,706
Billings, Montana	7,106	634
Boston, Massachusetts	5,791	997
Brownsville, Texas	617	4,369
Casper, Wyoming	7,638	465
Charleston, South Carolina	1,769	2,578
Chicago, Illinois	6,310	1,292
Columbus, Ohio	5,277	1,324
Denver, Colorado	5,673	615
El Paso, Texas	2,641	1,741
Fargo, North Dakota	9,274	793
Ft. Smith, Arkansas	3,188	2,326
Ft. Worth, Texas	2,361	2,814
Fresno, California	2,532	1,375
Hatteras, North Carolina	2,392	2,435
Houston, Texas	1,276	3,383
Jackson, Mississippi	2,202	2,656

TABLE III
AVERAGE ANNUAL DEGREE DAYS (Cont'd)

City	Heating Degree Days	Cooling Degree Days
Jacksonville, Florida	1,113	3,245
Kansas City, Missouri	4,888	1,946
Knoxville, Tennessee	3,590	1,947
Laredo, Texas	781	4,044
Los Angeles, California	1,451	1,026
Las Vegas, Nevada	2,425	1,771
Memphis, Tennessee	3,006	2,393
Miami, Florida	173	4,603
Minneapolis, Minnesota	7,853	1,012
Montgomery, Alabama	1,954	2,694
Nashville, Tennessee	3,513	2,093
New Orleans, Louisiana	1,175	3,365
New York, New York	5,050	1,234
North Platte, Nebraska	6,546	1,073
Oklahoma City, Oklahoma	3,519	2,092
Phoenix, Arizona	1,492	2,691
Raleigh, North Carolina	3,075	1,927
Red Bluff, California	2,546	1,418
Reno, Nevada	6,036	282
Rochester, New York	6,843	868
Sacramento, California	2,600	1,021

TABLE III
AVERAGE ANNUAL DEGREE DAYS (Cont'd)

City	Heating Degree Days	Cooling Degree Days
St. Louis, Missouri	4,469	1,851
Salt Lake City, Utah	5,463	764
San Antonio, Texas	1,579	3,137
San Francisco, California	3,069	210
Sault Sante Marie, Michigan	9,475	400
Seattle, Washington	4,438	197
Shreveport, Louisiana	2,117	2,900
Tallahassee, Florida	1,519	2,909
Tampa, Florida	674	3,669
Tucson, Arizona	1,776	2,085
Washington, DC	4,258	1,659
Winslow, Arizona	4,702	863
Yuma, Arizona	851	3,004

3.0 Cost and Savings

3.1 Define the breakeven condition and equipment life time. For most cases, breakeven will be a range rather than a point, since some data will have a subjective bias.

3.2 Determine the amount of building renovation and equipment adaption required to interface the systems with buildings. AR 415-17, Emperical Cost Estimates for Military Construction and Cost Adjustment Factors serves as a guide to renovation cost.

3.3 Tally cost and savings.

3.4 Divide total cost by savings/year, this yields the simple payback period.

3.5 Two methods of life cycle analysis are available. They are the present worth method and non-compounding simple interest method. They are described in Section 9 of the Automation and Centralization of Facilities Monitoring and Control Systems and Engineering Instruction for Preparation of Feasibility Studies for Total Energy Systems, respectively.

REFERENCES

1. Automation and Centralization of Facilities Monitoring and Control Systems, FESA, AD #AO26693.

2. Engineering Instruction for Preparation of Feasibility Studies for Total Energy Systems, OCE, (DAEN-MCE-U).

3. A Report on the Economic Feasibility of an Energy Control System for Fort Monroe, FESA-RT-2027.

4. AR 415-17, 9 August 1976, Emperical Cost Estimates for Military Construction and Cost Adjustment Factors.